Learning by Observation for Surgical Subtasks: Multilateral Cutting of 3D Viscoelastic and 2D Orthotropic Tissue Phantoms

February 12, 2019

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Paper information

Title	Learning by Observation for Surgical Subtasks: Multilateral Cutting of 3D Viscoelastic and 2D Orthotropic Tissue Phantoms
Author(s)	Adithyavairavan Murali, Siddarth Sen, Ben Kehoe, Animesh Garg, Seth McFarland, Sachin Patil, W. Douglas Boyd, Susan Lim, Pieter Abbeel, Ken Goldberg
Year	2015
Conference	IEEE ICRA (ICRA)
Highlights	Best Medical Robotics Paper Finalist PhD work Multilateral manipulation Learning By Observation (LBO) Simple approach but effective results

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Introduction

- Object: Repetitive surgical tasks automation
- Method: Building a Finite State Machine (FSM) via Learning By Observation (LBO)
- Evaluation:
  - Debridement of viscoelastic tissue phantoms (3d-DVTP)
  - Pattern cutting of orthotropic deformable tissue phantoms (2d-PCOTP)

Figure 1: 3D debridement

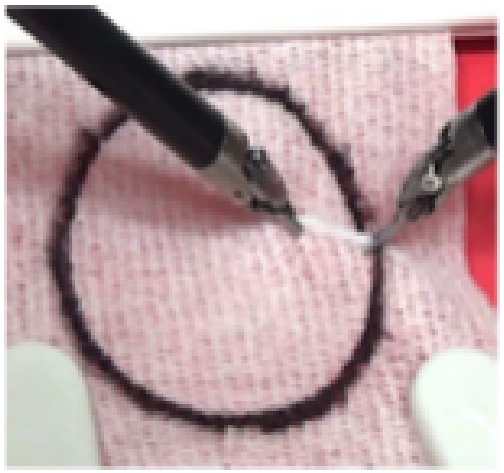

Figure 2: 2D pattern cutting

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Challenges:

- Interaction with deformable tissue
- Learning from expert demonstration
- Segmentation of demonstration into sequences

Current:

- Modelling of deformable tissue is computational expensive
- Handle it by learning from demonstration
- Manual or automatically segmentation

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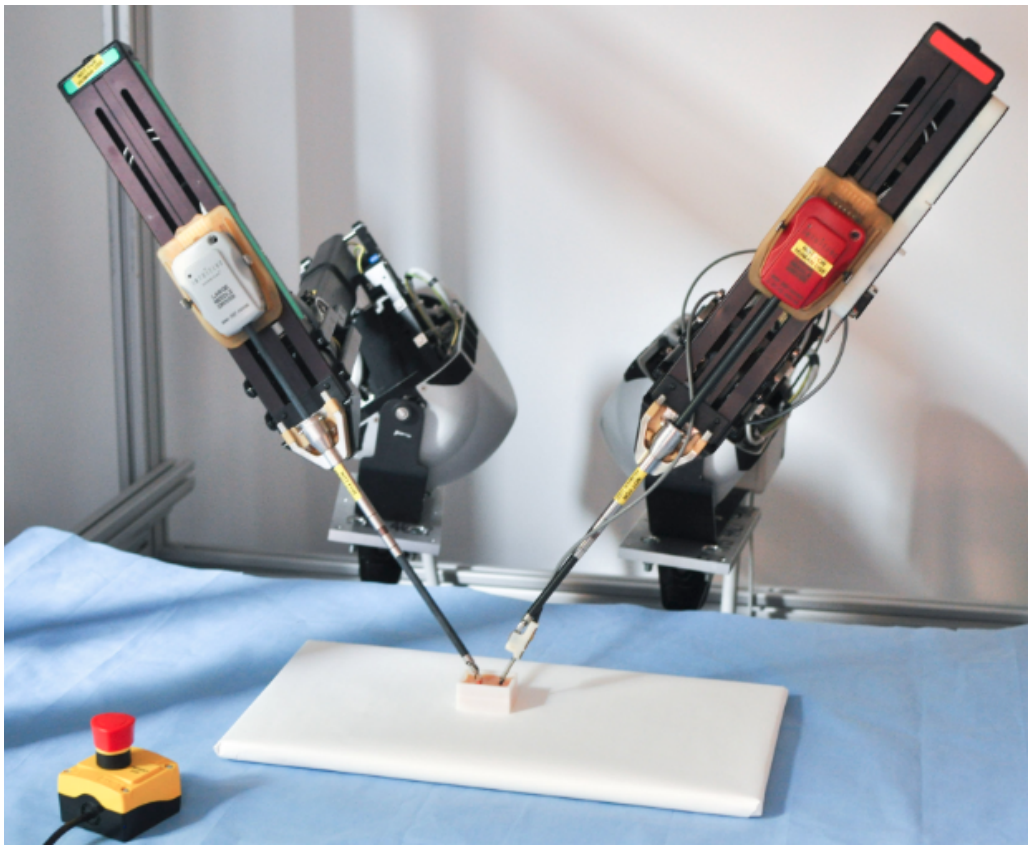
Set-up

Hardware:

- Da Vinci research kit (a tele-operated surgical platform)
- Stereo camera

Software:

- robot control program by JHU
- OpenCV



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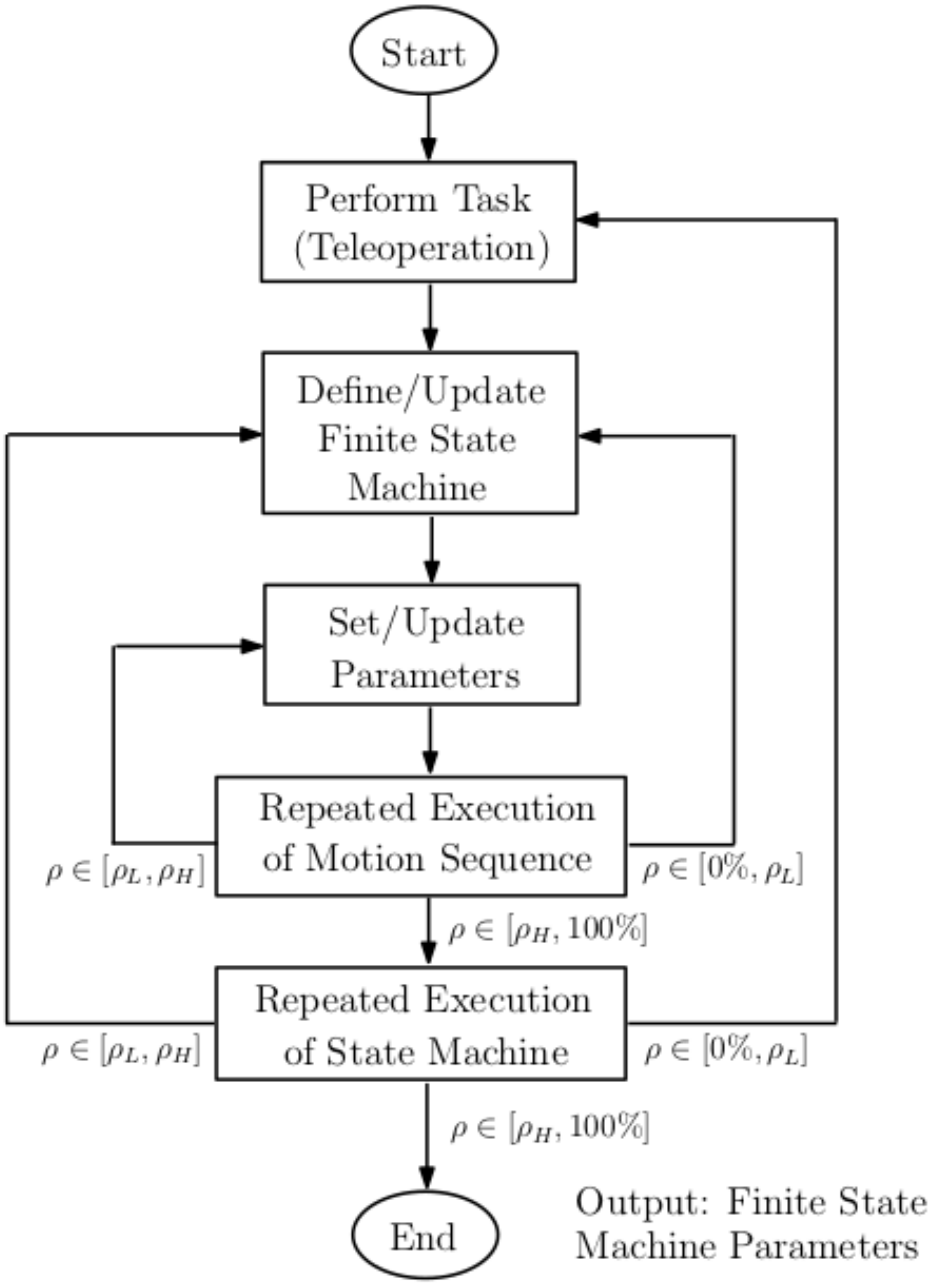

ρ - Repeatability

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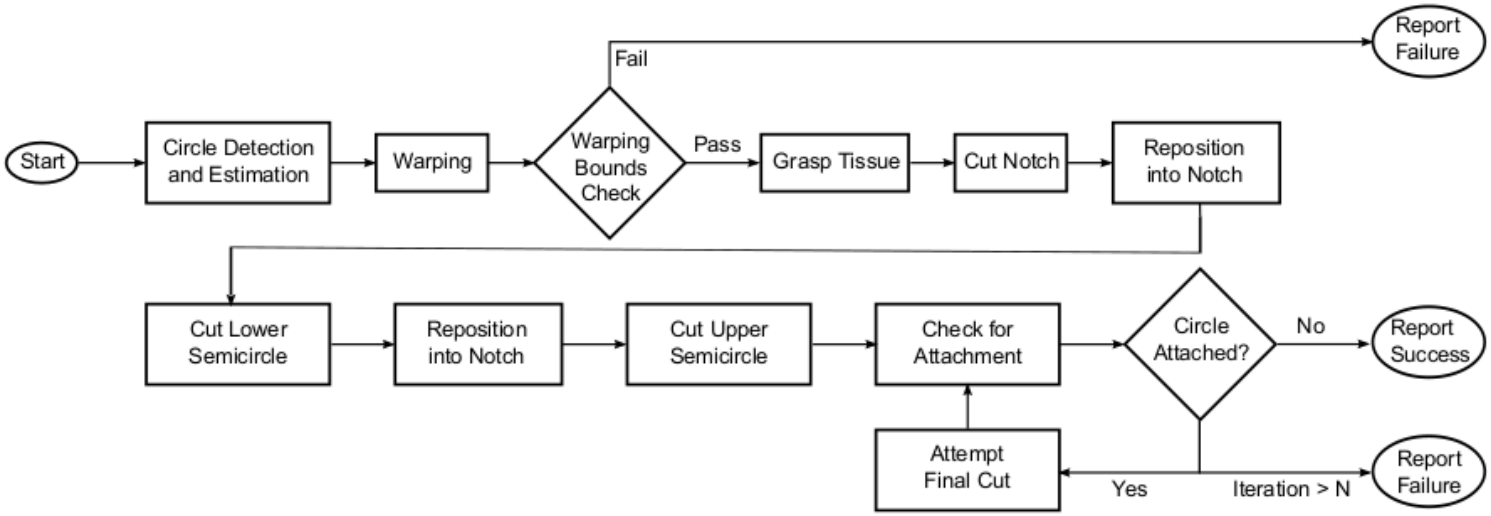
Finite state machine

Finite state machine for 2D pattern cutting:



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3D debridement

High success rate in 3D debridement:

Trial	Length (mm)	Outcome	Retrac-tions	Cut Failures	Time (s)	
					Total	Mean
1	21	Success	3	0	70	20.3
2	22	Success	3	0	70	20.3
3	27	Success	3	0	73	21.3
4	27	Success	4	1	94	20.5
5	24	Success	3	0	73	21.3
					76	20.8

Linear targets

Trial	Targets	Failures		Time (s)	
		Detection	Cut	Total	Mean
1	5	0	0	128	23.2
2	5	0	0	127	23.0
3	5	0	0	125	22.6
4	5	0	0	128	23.2
5	5	0	0	128	23.2
6	5	0	0	127	23.0
7	5	1	1	103*	23.5
8	5	0	0	125	22.6
9	5	0	0	125	22.6
10	5	0	0	124	22.4
	50	1	1	—	22.3

Spherical targets

Video.

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Lower success rate in pattern cutting:

Trial	Success	Score	Failed State	Transl. (mm)		Total Time
				x	y	
Demonstration		99.86		0.0	0.0	263
1	Success	99.81	—	26.4	-1.0	284
2	Failure	—	Notch	2.0	-0.5	130*
3	Failure	—	Notch	1.2	-3.0	120*
4	Success	94.52	—	4.5	-2.1	289
5	Failure	—	L.S.	2.0	-1.4	115*
6	Success	97.32	—	-1.2	-2.2	283
7	Success	99.12	—	4.0	-0.9	282
8	Failure	—	Notch	3.6	-0.9	131*
9	Failure	—-	U.S.	8.1	0.2	248*
10	Success	98.89	—	5.6	-0.4	279
11	Failure	—-	Notch	8.5	-1.8	129*
12	Success	99.87	—	5.6	-0.8	279
13	Success	100.00	—	6.6	0.4	284
14	Success	99.96	—	2.3	-1.6	285
15	Success	99.86	—	3.0	0.3	283
16	Success	98.96	—	9.3	-0.4	284
17	Success	98.39	—	8.5	-0.7	285
18	Success	98.94	—	10.5	-0.7	284
19	Success	98.85	—	9.3	0.5	284
20	Success	99.98	—	6.8	0.8	284
Mean	70%	98.89		6.5	1.0	284
Std. Dev.		1.47		5.6	0.8	2.5

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Future works and comments

Main conclusion: LBO can be effective in surgical task automation.
Future work:

- Improving speed and repeatability
- Automated (or semi-automated) segmentation of demonstrations
- Application to other subtasks

Personal comments:
Combination of current techniques performed impressive outcome
Any other feasible approaches?

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